

"Hot Spot" Radiation Absorption

There are many cases where the belief system is so absurd that scientists dismiss it instantly but never commit their arguments to print. I believe this is a mistake. Science, especially today, depends upon public support. Because most people have, unfortunately, a very inadequate knowledge of science and technology, intelligent decision making on scientific issues is difficult. Some pseudoscience is a profitable enterprise, and there are proponents who not only are strongly identified with the issue in question but also make large amounts of money from it. They are willing to commit major resources to defend their contentions. Some scientists seem unwilling to engage in public confrontations on borderline science issues because of the effort required and the possibility they will be perceived to lose a public debate.

- C. Sagan
Broca's Brain

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The human head is a complex structure of many different tissue types. Each of the tissues—skin, bone, cerebro-spinal fluid, fat, brain, dura, and others—absorbs and reflect

RF energy. But the amount of absorption and reflection is different from one tissue type to another. In addition, the human head is far from being a uniform structure.

The skull itself is a virtual landscape of ridges and bony prominences on its interior surface. These ridges and prominences, in addition to seams, are accompanied by areas of varying thickness. A quick look in any reference encyclopedia or anatomy reference will show that the inner structure of the human head exhibits some very pronounced interior ridges in addition to void (empty) areas such as the mastoid region.

Surrounding the skull, beneath the scalp, is a layer of subcutaneous fat. The thickness of that fat layer is different from person to person. Within the skull, of course, is the brain, which is held inside the meninges. We know the brain is also comprised of folds and seams.

All of these features in the internal landscape of the human head, in addition to the fact that head size also varies considerably, cause any penetrating RF radiation to be absorbed in a manner which depends strongly on the features of the head. In many instances the RF energy will interact with human head features in a way that directs and concentrates the absorption into small areas rather than being distributed uniformly throughout.

In 1955, researchers H. P. Schwan and G. M. Piersolcp reported that there is danger of causing burns when radiofrequency energy is applied over bony prominences. Their reasoning for this effect was that nonuniformities such as bone ridges and irregular fat layers cause the energy to be absorbed nonuniformly within the body or head. At "hot spots" excessive amounts of absorbed radiation can cause selective temperature rise of sensitive parts of the body. Consider what this means today, in

view of the previous finding and also in view of hand held portable phones.

For a human head structure this enhancement of absorbed energy is evidence of an energy absorption "hot spot" beneath the skull and at the surface of the brain. At frequencies of 750 MHz and above the absorption would be primarily in the brain tissue.⁵¹ Again, considering a human head, this research points out that the radio-frequency energy, in a broad range from about 500 MHz to 1,000 MHz, is preferentially deposited beyond the skull and absorbed into the brain.

Energy absorption "hot spots" of greater than ten times the overall average have already been described for a bone/brain interface. Many other "hot spots" within the human head are also well known.

Some interior "hot spots" are related to the radius of curvature of the human head. Other reasons for "hot spot" formation will be described subsequently, including the nonuniformities of skull structure and brain tissue within the head.

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It only takes a very short time to destroy living brain tissue. RF energy absorbed within a fraction of a second can be enough to damage and modify the structure of brain cells and molecules. For example, a few seconds of intense exposure is enough to kill laboratory rabbits with radiofrequency radiation. Researchers noted that

⁵¹ H. P. Schwan and G. M. Piersol, "The Absorption of Electromagnetic Energy in Body Tissues." *Irretrievable Review of Physical Medicine and Rehabilitation* (June 1955):424-48. 1A

*experiments in which the head area alone was directly irradiated suggest that the fatal outcome was the result of an excessive rise in brain temperature. The lethal effects of irradiation to a limited area of the body are different from those in which the entire animal is exposed.*⁵²

That warning was first provided in 1952.

Some researchers have reported that in order to obtain selective "hot spot" heating, it is necessary to expose the tissue to the near-zone fields of the energy source.⁵³

From their experimental data at 433 MHz, 750 MHz, and 918 MHz these researchers confirmed that energy is readily absorbed from the induction fields in the nearzone. The absorption within the brain was found to be about twenty times greater than in the skull and subcutaneous fat. That is certainly consistent with all of the earlier reported research.

J. C. Lin, Guy, and Caldwell performed thermal studies of rat bodies radiated in the near-zone.⁵⁴ Their measurements indicate an energy absorption (SAR) of 0.9 mW/g for a power density of only 1 mW/cm². They proposed that nonthermal effects may be masked by heating and that, even at low power density, absorption at local "hot spots" may produce thermal stimulation. This concept has serious implications. These researchers have

⁵² H. M. Hines, and J. E. Randall, *Electrical Engineering*, 71 (1952):879

⁵³ A. W. Guy, "Analyses of Electromagnetic Fields Induced in Biological Tissues by Thermographic Studies on Equivalent Phantom Models," *IEEE Transactions on Microwave Theory and Techniques MTT-19*, no. 2 (February 1971):205-14. '

⁵⁴ J. C. Lin, et al., "Thermographic and Behavioral Studies of Rats in the Near Field of 918-MHz Radiations," *IEEE Transactions on Microwave Theory and Techniques MTT-25*, no. 10 (October 1977):833-36. -

proposed that, even at low absorption levels microscopic "hot spot" destruction may be occurring unnoticed.

In one experiment 0.1 mW/cm² average power density resulted in 140 mW/g "hot spots" in radiated animals. Considering that they had earlier determined that 0.1 mW/cm² should result in an SAR of 0.09 mW/g, this latest finding indicates the presence of "hot spots" with enhancement of more than 1,500 times the expected level.

An important point brought out by this particular series of experiments is that within actual test subjects, whether laboratory animal or humans, RF energy can be concentrated into very high-intensity spots just as sunlight may be concentrated with a magnifying glass. Most of us are familiar with the intense heating effect of concentrated sunlight. The same intense effect occurs within living tissue at radiofrequency radiation "hot spot" locations.

These researchers used a power density level that was about one hundred times less than a human receives during portable cellular phone operation. Even so, the SAR 140 mW/g, was so high that tissue destruction would have been nearly immediate. For human brain tissue less than 5 mW/g is sufficient to cause a temperature rise that initiates tissue damage.

Lin also acknowledged that energy absorption occurs vary rapidly.⁵⁵ So, during short exposures of from a few seconds to a few minutes, very little heat conduction—heat energy movement through the tissue—takes place. This is important in view of "hot spot" absorptions. If a "hot spot" situation exists, rapid energy absorption

⁵⁵ J. C. Lin, "On Microwave-Induced Hearing Sensation," *IEEE Transactions on Microwave Theory and Techniques MTT-25*, no. 7 (July 1977):605-13.

will have maximum destructive effect because, in accordance with Lin's reported findings, very little of the heat caused by the absorption will have an opportunity to dissipate. As Lin puts it,

Because, microwave absorption occurs in a very short time, there will be little chance for heat conduction to take place.

The conduction of heat takes much longer. Alternatively, he advises that

the temperature decay is therefore a slowly varying function of time . . .

What we expect then is rapid heating and slow cooling. At "hot spots" the inability of biological tissue to get rid of excess heat quickly and efficiently may yet be another mechanism leading to destructive exposure, even at levels previously thought to be incapable of raising tissue temperature.

If "hot spots" occur at localized or microscopic regions within the brain, where there are no thermal or sensory receptors, there is no reason to expect that the body will attempt to compensate for the overheating. The human brain simply does not have the capacity to prevent the damage.

There are, of course, exposures that will result in "hot spot" damage that is significant enough to be readily observable. There is also another less noticeable type of "hot spot" damage. Microscopic "hot spots" can selectively destroy or damage tissue and leave no outwardly visible traces of that damage. In the previous chapter exactly

this type of microscopic "hot spot" damage was described and documented.

Humans operating RF radiating devices expose themselves to similar damage. Within the human brain the regions most closely associated with RF radiation exposures, the temporal lobes, are also the regions most tolerant to damage—that is, most tolerant in the sense that one would never know of an injury. It is possible to continually create uncountable millions of microscopic injuries within these regions and yet the damage could go unnoticed externally even with MRI or CT examination. But the damage would produce an effect internal to the injured person.

Recall what we learned earlier from Michaelson and consider it once again within the context of virtually millions of microscopic brain cell injuries:

It should be understood that a cumulative effect is the accumulation of damage resulting from repeated exposures each of which is individually capable of producing some small degree of damage. In other words, a single exposure can result in covert thermal injury, but the incurred damage repairs itself within a sufficient time period, for example hours or days, and therefore is reversible and does not advance to a noticeable permanent or semi permanent state. If a second exposure or several repetitive exposures take place at time intervals shorter than that needed for repair, damage can advance to a noticeable stage.⁵⁶

⁵⁶ S. M. Michaelson, "Human Exposure to Nonionizing Radiant Energy—Potential Hazards and Safety Standards," *Proceedings of the IEEE* (April 1972):389-421.

Recall that hot spot absorption is a term that researchers themselves have taken to describe exactly what is happening at specific locations within the brain—or any other tissue mass. That is, excess radiofrequency energy is being deposited into some small region of the brain. Which regions of the brain will be subjected to "hot spot" absorption depends on a number of factors related to head size, shape, curvature, subcutaneous fat layer thickness, internal skull structures, and voids within the skull.

Equally important, "hot spots" are dependent on the type of antenna, the physical structure of the telephone, and how the user holds the telephone during operation. All of these variables combine to create a complex matrix of enhancement mechanisms to provide different energy absorption "hot spots" for users. Unless the radiating elements, including antenna and telephone case, are far from the head of the user "hot spots" should be expected.

This information was well understood by cellular telephone manufacturers during the development phase of the 1970s. Their own publications acknowledge as much. In one such infrequent industry report researchers identified an energy absorption "hot spot" located in the temporal region of the human head.

The temperature profiles generated by both antennas inside the head of the simulated operator indicate the presence of a "hot spot" about 1 in below the surface of the temporal bone.⁵⁷

⁵⁷ Q. Balzano, et al., "Energy Deposition in Simulated Human Operators of 800-MHz Portable Transmitters," *IEEE Transactions on Vehicular Technology* VT—27, no. 4 (November 1978):174-81.

These experiments were performed at 840 MHz, which is within the portable cellular telephone transmit band.

Industry researchers acknowledge the need for concern of operator exposure to radiofrequency radiation because

the 800-900 MHz band is very close to the frequencies used for medical diathermy (918 MHz). Diathermy applicators are well known for efficiently depositing energy deep within human tissue.

They propose that the energy penetrates deep and causes "hot spot" absorption at about one inch below the surface of the temporal bone. Other researchers have confirmed that curvatures of the head will lead to various "hot spots" and that some of the "hot spots" are strikingly pronounced. The industry researchers conclude that

SAR peaks (sometimes called "hot spots") are probably associated with the "focussing" of this EM energy in the frontal bone.

These experiments, conducted in 1978, were performed with a portable radio, not a portable cellular telephone. Therefore, the antenna was located at the front of the head. Comparing the front of the human skull with the rear, we notice that equivalent curved areas of the skull are located at the rear on each side above either ear. As such, any focusing mechanism that is described would be identically replicated at the rear portion of the human head. Portable cellular telephone antennas are, most typically, disposed immediately adjacent to one of those curved regions during operation. Surface curvature is of primary importance. The region of the human head above and behind each ear is a

region of small radius of curvature. That is, it curves a great amount. If the curvature of that region were completed into a full ball shape the size would be about 4 or 5 cm in diameter or a radius of 2-2.5 cm. That is well within the range of sizes found by researchers to support "hot spot" generation.

In the region through the width of the head, that is, ear to ear, the thickness is generally less than from front to back. When considering the structures that support "hot spot" generation these surface and structural non-uniformities of the human head are more important than the overall head size.

Consider now the same structural features of the heads of children and smaller adults. The curved area behind and above the ears is more severe, and the total width of the head is correspondingly reduced. Since "hot spot" absorption is a function of head curvature, some humans, both children and adults, are more susceptible with this type of "hot spot" formation. Long before the introduction of cellular telephones, researchers provided data that indicated that children absorb approximately 50 percent more radiation within their heads than do adults.⁵⁸ These results are provided for plane-wave, far field exposures and do not consider any of the enhancement effects that are introduced by near-zone operation of cellular telephones. This same research study also shows that thin men absorb about 33 percent more radiation than an average 70 kilogram (155 - pound) man.

⁵⁸ C. H. Durney, et al., "An Empirical Formula for Broad-Band SAR Calculations of Prolate Spheroidal Models of Humans and Animals," *IEEE Transactions on Microwave Theory and Techniques* MTT-27, no. 8 (August 1979):758-63.

Lin placed the increased absorption effect into a better perspective when he reported that "hot spot" energy absorption can be as much as ten times higher at certain areas within the brain.⁵⁹ From experiments performed using models of the human head he reported energy absorptions in the center of the head that were even higher than absorption levels near the surface. This is a prime example of "hot spot" energy deposition.

The presence of nonuniform energy absorption that treated the new type of "hot spot" was initially characterized by H. P. Schwan.⁶⁰ The "hot spots" Schwan discussed were somewhat different from those we have considered previously. In the earlier consideration of "hot spots" the focus was on nonuniform radiation, nonuniform absorption characteristics, and nonuniformities within the head. But this researcher performed experiments using various diameter head models. His conclusions are that as head diameter is reduced energy-absorbing "hot spots" become pronounced. The research found that for heads significantly smaller than that of a mature man the "hot spot" effect increases and so does the amount of energy that is absorbed into the interior of the brain. Clearly this indicates an increased risk of "hot spot" absorption within the brains of women and children, with small children being at maximum risk a "hot spot" absorption within their brains. Keep in mind that this is an additional "hot spot" formation mechanism

⁵⁹ J. C. Lin, "Interaction of Two Cross-Polarized Electromagnetic Waves with Mammalian Cranial Structures," *IEEE Transactions on Bionomedical Engineering* BME-23, no. 5 (September 1976):371-75.

⁶⁰ H. P. Schwan, "Microwave Radiation; Hot Spots in Conducting Spheres by Electromagnetic Waves and Biological Implications," *IEEE Transactions on Biomedical Engineering* BME—19, no. 1 (Janunry, 1972):53-58.

that may be present along with the other "hot spot" absorptions described earlier.

Other researchers have recorded this same "hot spot" absorption characteristic across a wide frequency range.⁶¹ They also confirmed that the "hot spot" absorption is dependent on the diameter of the head model that they used. As the diameter decreased the absorption effect became more pronounced. Most notably, the greatest absorption enhancement occurs at frequencies between 800 MHz and 1,000 MHz - effectively covering the portable cellular telephone transmit band.

Researchers also reported that maximum "hot spot" energy absorption enhancements occur in the frequency region around the cellular telephone frequencies.^{62,63} Of course, they didn't report their findings as being particularly noticeable for the portable cellular telephone transmit-band, because most of this work took place during the 1970s, from about 1972 through 1976. There were no cellular telephones on the market at that time, but they were under development in the research labs. All of which means that this alarm raised about "hot spot" RF energy absorption related to head size and children has been known in the industry since long before the very first portable was put into the anxious hands of the very first customer.

⁶¹ H. N. Kritikos and H. P. Schwan, "Formation of Hot Spots in Multilayer Spheres," *IEEE Transactions on Biomedical Engineering* (March 1976):168-72.

⁶² H. P. Schwan, "Microwave Radiation; Hot Spots in Conducting Spheres by Electromagnetic Waves and Biological Implications," *IEEE Transactions on Biomedical Engineering BME—19*, no. 1 (January 1972):53-58.

⁶³ H. P. Schwan, "Microwave Radiation; Biophysical Considerations and Standards Criteria," *IEEE Transactions on Biomedical Engineering BME—19*, no. 4 (July, 1972):304-12.

These researchers also reported that the "hot spots" are evident in head sizes up to about 6 1/2 inches in diameter. That's a fairly large head diameter and leads to the conclusion that since many human heads are smaller than 6 1/2 inches in diameter, many human exposures to cellular telephone radiofrequency radiations would include this type of "hot spot" formation. With reference to figures that document their research findings C. C. Johnson and A. W. Guy state:⁶⁴

The figures clearly illustrate the intense fields and associated absorbed power density directly in the center of the human head . . . for 918 MHz exposure.

Available research has already been presented here that verifies that the radiofrequency radiation absorption characteristics of biological tissue are indistinguishable, that is, virtually the same, for both 845 MHz and 918 MHz. Whatever absorption characteristics are found at 918 MHz will also hold at 845 MHz. Similarly those energy absorption characteristics found to be true at 750 MHz will also be true at 825 MHz and again at 918 MHz. This entire range of frequencies is the same with respect to energy deposition into biological tissue. Usually, as radiofrequency radiation penetrates into the brain it is being absorbed so that as it propagates more deeply there is less remaining and the magnitude, or strength, of the radiation decreases with increasing depth. But this is not the situation where "hot spots" exist. Johnson and Guy report that, at 918 MHz the depth

⁶⁴ C. C. Johnson and A. W. Guy, "Non Ionizing Electromagnetic Wave Effects in Biological Materials and Systems," *Proceedings of the IEEE*, 60, no. 6 (June 1972):692-718. C

of penetration is 3.2 cm, and that's consistent with what we've reviewed earlier. However they found that

...for human brain exposed to 918-MHz power, the absorption at a depth 2.3 times the depth of penetration (depth of penetration=3.2 cm) is twice the absorption at the surface. This corresponds to a factor greater than 200 times that expected . . .

This means that at a depth within the human brain of about 7 cm (almost 3 inches) "hot spots" were found that produced energy absorption 200 times greater than would be the case if no "hot spot" existed.

More startling is the observation that at this great depth within the brain the "hot spot" absorption is actually two times greater than the absorption near the surface where the radiation is assumed to be strongest.

The regions of intense absorbed power density are due to a combination of high refractive index and the radius of curvature of the model which produces a strong focusing of power toward the interior of the sphere.

Focusing due to head curvature is held responsible for the "hot spot" absorption. With this knowledge, along with earlier research findings reporting the same results, we can understand how people with smaller or rounder skull shapes may be at increased risks and how people who operate cellular telephones with antennas placed in particularly dangerous positions at their heads could also be in greater danger.

W. T. Joines and R. J. Spiegel⁶⁵ expanded experimentation and computations with human head models by working with a structure comprised of six layers: skin, subcutaneous fat, skull, dura, cerebro-spinal fluid, and brain tissue. A total thickness of the five layers that surround the brain is given as 1.10 cm. However, we must keep in mind that the layers, most principally the subcutaneous fat layer, will vary appreciably from one human to another.

Computerized calculations indicate enhanced energy absorption in the six-layer models of the human head compared to what had been reported by earlier researchers. To this point we have noted that developments moving from flat homogeneous models—slabs of simulated tissue—to two layered spherical models and then to six-layer model consistently yield findings of higher RF energy absorption. As the models become more complex and increasingly representative of an actual human head the findings continue to indicate that the energy absorption is much higher than previously thought. Although the primary importance of their work rests with the effects of the multilayered model, these researchers also found that an absorption peak occurs at approximately 750 MHz and near 2,100 MHz for a 7 cm radius sphere.

Interestingly, both of these frequencies are almost exactly where the cellular telephone industry has chosen to operate their portable transmitters. The PCS devices operate near 2,100 MHz—actually in the 1700—1900 MHz range.

⁶⁵ W. T. Joines and R. J. Spiegel, "Resonance Absorption of Microwaves by the Human Skull," *IEEE Transactions on Biomedical Engineering* (January 1974):46-48.